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OPTIMIZATION OF ELECTRIC DISCHARGE MACHINING PARAMETERS FOR Al–3 WEIGHT % NANO SiC_p COMPOSITES USING COPPER ELECTRODE

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Abstract

Aluminium matrix composites have seen the most wide spread applications and it is the most emerging material in the automotive, aircraft, defence and other applications. Silicon carbide particles have a high modulus of elasticity, higher hardness, low coefficient of thermal expansion and density which when reinforced with Al-alloys make them highly attractive materials. These composite materials offer improved properties such as high strength to weight ratio, high stiffness, corrosion resistance, low coefficient of thermal expansion and closer dimensional tolerance. The complexity and degree of precision required for components in industries need holes to be straight, accurate and exactly positioned that is possible by non traditional machining like electric discharge machining.

In the present study the effect of machining responses MRR, and TWR on the Al- 3 wt. % Nano SiC Composite plate fabricated through ultrasonic assisted stir casting process. The experiments were conducted on ELECTRONICA smart S 50 CNC EDM using copper electrode of 15.1 mm diameter with side flushing. The experiments were performed under various parameters setting of Pulse on Time (Ton), Peak Current (Ip) and Servo voltage (V). L_{27} full factorial design, three factor-three level setup was used in the experiment. Minitab software was used for analysis and formulation of linear mathematical regression equations. The objective functions were optimized in MATLAB using Genetic Algorithm with terminating current iteration 51. The input parameters Ton, Ip and V were varied from 200 to 400 micro second, 20 to 40 amperes and 70 to 90 Volt respectively. Maximum value of MRR was obtained at Ton (396.413μs), Ip (39.999 A) and V (84.76 V). Minimum value of TWR was obtained at Ton (344.71μs), Ip (39.994 A), and V (70.005 V).

Keywords: Electric Discharge Machining, Material Removal Rate, Tool Wear Rate, Pulse on Time (Ton), Peak Current (Ip), Servo voltage (V), and Design of Experiment.

1. INTRODUCTION

Electric discharge machining (EDM) is an electro-thermal unconventional machining in which materials removed by controlled erosion of metals through a series of repetitive electric spark between the tool and work piece. The electrical energy is used to generate electric spark (arc) between the electrode and work piece along the path of least resistance. In the event of spark discharge, there is a flow of current across the tool electrode – work piece gap. The energy content of a single spark discharge can be

expressed as a product of pulse on time and peak current (Ton×Ip). Energy contained in a tiny spark discharge removes a friction of work piece material in the form of melting, evaporation, scattering of particle, and leaving behind a small crater on the work piece surface as shown in a figure 1. The repetitive cycles of spark discharge result in bulk material removal of work piece. During the process, however, a fraction of material is also removed from the tool electrode called as electrode wear.

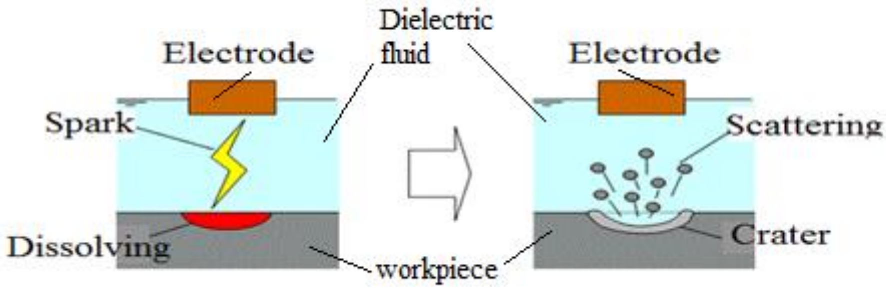

Fig.1 Electric spark between work piece and electrode

This process is based on melting temperature, not hardness of work piece, so some very hard, tough or brittle materials can be machined this way.

2. FABRICATION OF LM6 Al–3 wt.% NANO SiC_P COMPOSITE PLATE

Apparatus and Materials required to Fabricate of Al–3wt. % Nano SiC_p composite plates are Ultrasonic Stir Casting furnace, Aluminium–LM6 Casting alloy, SiC_p Nano powder, Weighing Machine, Graphite Crucible, Mild Steel Mould (225*145*120 mm), Stirrer, Ultrasonic Probe, Cutting Grinder and hacksaw, etc. Square rods of raw material (LM6 Al alloy) were cut into small pieces with the help of cutting grinder. Before take these pieces inside a graphite crucible, the crucible preheated inside the furnace so that the moisture content of the crucible is removed. Approximate 1250 grams LM6 Al alloy was put in the crucible and Heating the crucible above the liquids temperature near about 680 ℃ inside the furnace and allow it to become completely liquid. Stirring of molten metal to homogenize the temperature and then adding the 38 grams SiC Nano powder into molten alloy. Nano powder was preheated (300℃) before maxing in a molten alloy. Again stirring was done for 10 minutes, after that Ultrasonic Probe is inserted for 5 to 7 minutes for proper dispersion of SiC Nano particles and then pouring the molten metal into the mild steel mould.

Fig. 2 Die after pouring of molten Metal in (a) and Composite plate after machined in (b)

The casting was then taken out and the gates were cut. The plates were then machined in uniform thickness as shown in figure 2.

2.1 DESIGN OF EXPERIMENT (DOE)

Design of Experiments (DOE) is a study of the factors that determine the key process input variables and the source of the variation or have an influence on the mean of the output. In this paper DOE having 3 levels each of 3 factors, 3^3 full fractional designs with 27 treatment combination as show in a table 2. Three machining parameters were identified and their levels were fixed as given in the table 1.

Table 1 Factor and their Levels

Machining parameter	Symbol	Unit	Level one	Level two	Level three
Peak Current	Ip	Amperes (A)	20	30	40
Pulse on time	Ton	Microsecond (μs)	200	300	400
Servo Voltage	V	Volt (V)	70	80	90

2.2 RESPONSE VARIABLE

The response variables (output parameters) of the electric discharge machining process considered in the present study are Material removal rate (MRR) and Tool wear rate (TWR). These variables were measured during the experiment as giving below.

2.2.1 Material removal rate (MRR)

MRR is expressed as the ratio of the difference of weight of the workpiece before and after machining to the machining time.

$$MRR = (W_{jb} – W_{ja})/t$$

2.2.2 Tool wear rate (TWR)

TWR is expressed as the ratio of the difference of weight of the tool before and after machining to the machining time.

$$TWR = (W_{tb} – W_{ta})/t$$

Whereas,

$\mathbf{W_{jb}}$ and $\mathbf{W_{ja}}$ is the weight of the work piece before and after machining respectively, $\mathbf{W_{tb}}$ and $\mathbf{W_{ta}}$ is the weight of the tool before and after machining respectively, and **t** is the machining time.

3. ELECTRICAL DISCHARGE MACHINING OF COMPOSITE PLATES

After casting of Al-3 wt. % SiC_p Nano composite plates, the electrical discharge machining was done on the plates. The initial weight of the tool and work piece was measured. The work piece was clamped in the vice and the vice was placed in the tank of the machine as shown in figure 3a. Before starting the machining the value of input parameters i.e. servo voltage (V), peak current (Ip), and pulse on time (Ton) were put in the machine setup at which experiment were to be conduct. The final weight of the tool after drilling of each hole was measured and recorded as shown in observation table.

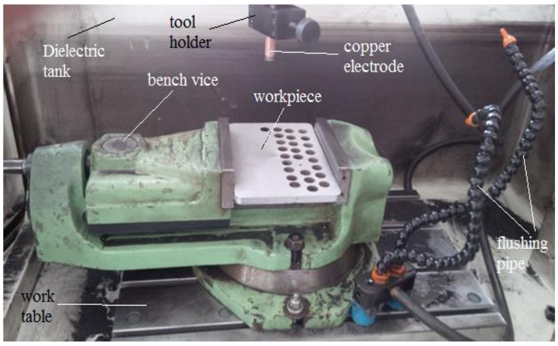

Fig. 3a Dielectric tank of the machine

Fig. 3b Composite plate after 27 hole

27 possible Combination of Ton, Ip and V is giving in the observation table and corresponding measured value of response variable (MRR and TWR) also shown in that table.

Table 2 Observation table

Run	Ton (μs)	IP (A)	V (V)	Time (sec.)	Weight of work piece in gm		Weight of electrode (Tool) in gm		MRR (10^{-3}) (gm/s)	TWR (10^{-3}) (gm/s)
					W_{jb}	W_{ja}	W_{tb}	W_{ta}		
1	200	20	70	3450	808.3	803.6	115.7	115.6	1.3623	0.028985
2	200	20	80	3226	803.6	798.8	115.6	115.5	1.4879	0.0309981
3	200	20	90	3237	798.8	794	115.5	115.3	1.4285	0.0617856
4	200	30	70	2465	794	789.1	115.3	115.2	1.9878	0.0405679
5	200	30	80	2284	789.1	784.2	115.2	115.1	2.1453	0.043782
6	200	30	90	2290	784.2	779.5	115.1	115	2.0524	0.043668
7	200	40	70	1902	779.5	774.6	115	114.8	2.5762	0.00105152
8	200	40	80	1799	774.6	769.5	114.8	114.6	2.8349	0.001111728
9	200	40	90	1781	769.5	764.8	114.6	114.5	2.6389	0.0561482
10	300	20	70	2423	764.8	759.7	114.5	114.4	2.1048	0.041271
11	300	20	80	2207	759.7	754.7	114.4	114.3	2.2655	0.04531
12	300	20	90	1817	754.7	749.8	114.3	114.1	2.6967	0.00110071
13	300	30	70	1431	749.8	744.8	114.1	114	3.494	0.069881
14	300	30	80	1476	744.8	740	114	113.8	3.252	0.001355
15	300	30	90	1388	740	735	113.8	113.7	3.6023	0.072046
16	300	40	70	1152	735	730.1	113.7	113.5	4.2534	0.00173611
17	300	40	80	1271	730.1	725.1	113.5	113.3	3.9339	0.00157356
18	300	40	90	1065	725.1	720.1	113.3	113.2	4.6948	0.093896
19	400	20	70	1669	720.1	715.2	113.2	113	2.9358	0.001198322
20	400	20	80	1484	715.2	710.7	113	112.9	3.0323	0.067385
21	400	20	90	1652	710.7	706	112.9	112.8	2.845	0.060532
22	400	30	70	1213	706	701.2	112.8	112.7	3.9571	0.08244
23	400	30	80	964	701.2	696.4	112.7	112.5	4.9792	0.00207468
24	400	30	90	1129	696.4	691.6	112.5	112.4	4.2515	0.088573
25	400	40	70	928	691.6	686.7	112.4	112.3	5.2801	0.00107758
26	400	40	80	908	686.7	681.8	112.3	112.1	5.3964	0.00220264
27	400	40	90	843	681.8	676.5	112.1	111.9	6.287	0.00237247

3.1 REGRESSION ANALYSIS: MRR and TWR VERSUS Ton, Ip, V

The regression equation of MRR

$$MRR = - 4.24 + 0.0114\times Ton + 0.0985\times Ip + 0.0141\times V$$

Table 3 Analysis for MRR

Predictor	Coefficient	SE Coefficient	T	P
Constant	- 4.2449	0.8056	- 5.27	0.000
Ton	0.0113612	0.0008860	12.82	0.000
Ip	0.098538	0.008860	11.12	0.000
V	0.014142	0.008860	1.60	0.124
	S = 0.375896	R-Sq = 92.7%	R-Sq(adj) = 91.7%	

The regression equation of TWR

$$TWR = -\ 0.0296 - 0.00000013 \times Ton - 0.000986 \times Ip + 0.00118 \times V$$

Table 4 Analysis for TWR

Predictor	Coefficient	SE Coefficient	T	P
Constant	-0.02961	0.6704	0.663	0.663
Ton	-0.00000013	0.00007373	-0.00	0.999
Ip	-0.0009855	0.0007373	-1.34	0.194
V	0.0011773	0.0007373	1.60	0.124
	S = 0.0312808	R-Sq = 15.9%	R-Sq(adj) = 4.9%	

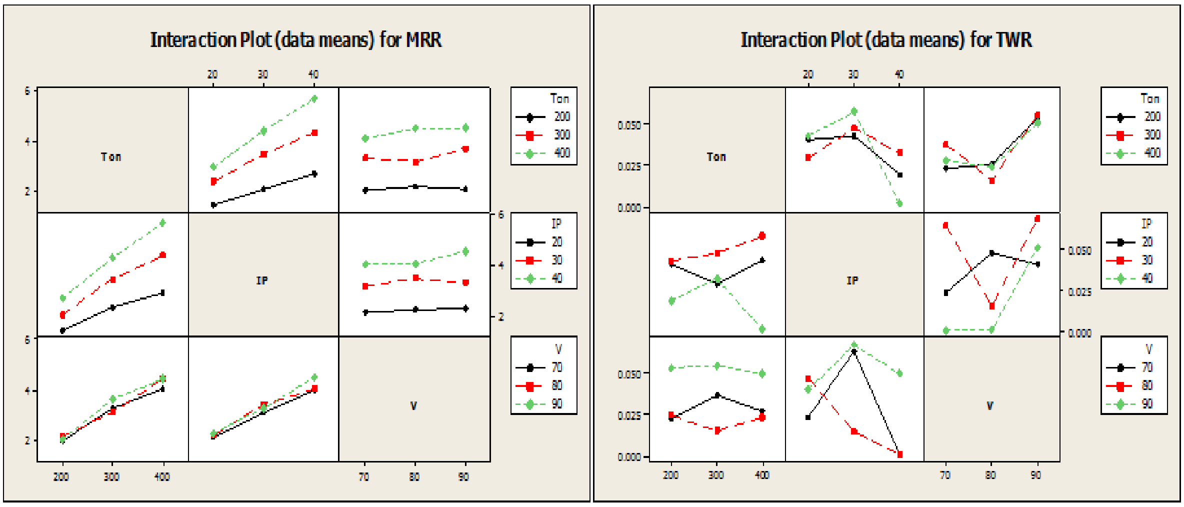

Fig. 4 Interaction plot for MRR and TWR

3.2 OPTIMIZATION OF OBJECTIVE FUNCTION BY GENETIC ALGORITHMS

Though there is lack of fit the regression equation (objective function) of MRR and TWR has got R-sq value of 92.7% and 15.9% respectively. These equations are optimized using genetic algorithm in MATLAB software tool box with current iteration 51. The maximum and minimum boundary conditions of both (MRR and TWR) objective function are [400, 40, 90] and [200, 20, 70] respectively.

Objective function of MRR

$$MRR = -\ 4.24 + 0.0114 \times Ton + 0.0985 \times Ip + 0.014 \times V$$

Objective function of TWR

$$TWR = -\ 0.0296 - 0.00000013 \times Ton - 0.000986 \times Ip + 0.00118 \times V$$

Optimum value of MRR and TWR were obtained 5.41410123347047 $\times 10^{-3}$ gm/sec and 0.0138262225718686 $\times 10^{-3}$ gm/sec respectively. The graphs obtained for best fitness giving below.

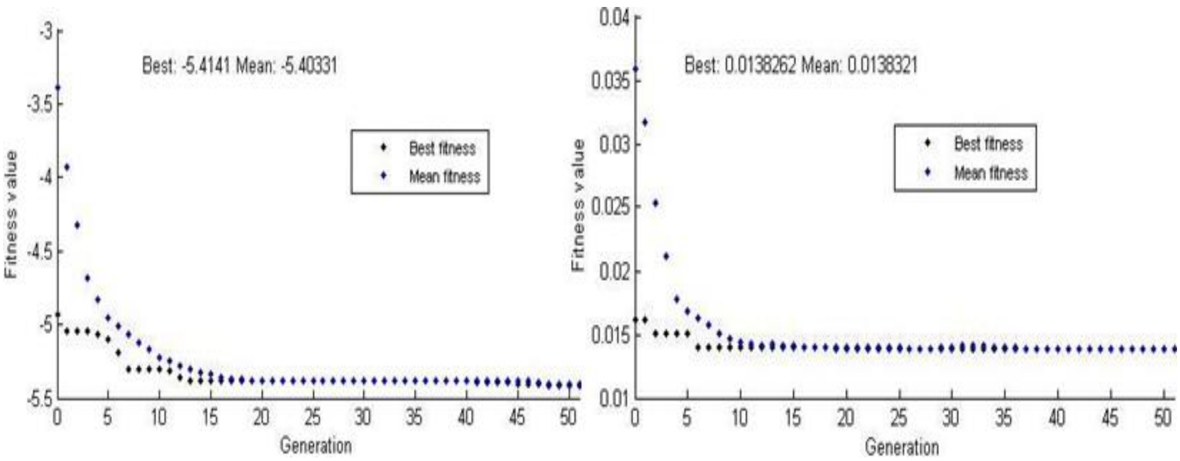

Fig. 5 best fitness Graph for MRR and TWR

4. CONCLUSIONS

- Optimum (Maximum) value of MRR is 5.41410123347047 x10^{-3} gm/sec at Pulse of Time (396.413 µs), Peak Current (39.999 A) and Servo Voltage (84.76 V).
- Optimum (Minimum) value of TWR is 0.01382622257186886 x10^{-3} gm/sec at Pulse of Time (344.71 µs), Peak Current (39.994 A), and Servo Voltage (70.005 V).
- It was observed that the MRR increases is directly proportional to the peak current and pulse on time but inversely proportion to the servo voltage.
- Material removal rate increasing with increase in peak current keeping the voltage constant and the current was varied from 20 to 40 amperes. Maximum value of MRR observed at 39.999 amperes.
- Tool wear rate first increased with peak current but after 30 amperes its start to decrease and minimum value of tool wear rate obtained at 39.994 amperes.

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